Name of discipline:

Transmission systems of access networks (TSAN)

Lecturer - Oreshkov Vasiliy Ivanovich

Lecture 7

OPTICAL ACCESS NETWORKS

Concept of optical networks construction

Architecture of optical access networks [FTTx (Fiber to the ...)] is characterized by a degree of approximation of the optical network terminal to the user. Standardization Sector of the International Telecommunication Union (ITU-T) identifies several specific options.

The concepts of FTTx (Fiber to the ...) suggest a section with the distribution of copper cables, but it is shorter than the more bandwidth (Fig. 7.1).

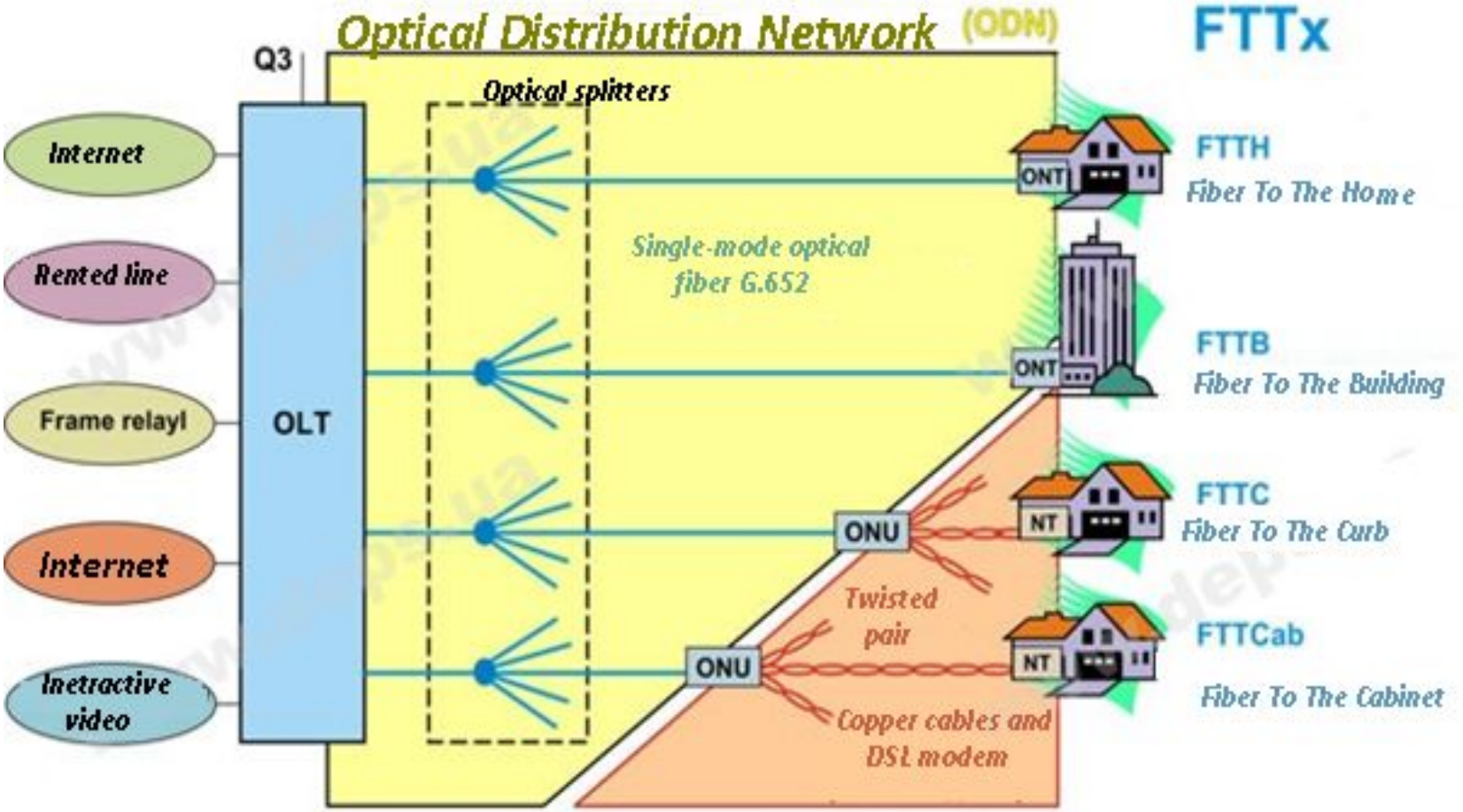

Fig. 7.1. Possible architectures of optical access networks

Historically, the first solutions appeared FTTN and FTTC.

To date, FTTN is mainly used as low-cost and quick-to-implement solution where there is a junction, "copper" infrastructure and laying of optical fiber is unprofitable. Everybody is aware of the associated decision problem: the low quality of services is provided, due to specific problems lie in the sewers of copper cables, a significant limitation on the speed and number of connections in a single cable.

FTTC is an enhanced version of FTTN. In the case of FTTC copper cables are using mainly and are placed inside buildings, which usually are not subject to the problems connected with water seepage telephone sewer lines with long and quality of copper conductors used, which allows to achieve higher transmission rate at the copper section.

FTTC is primarily intended for users who are already using xDSL technology, or PON, and cable operators: the implementation of this architecture will allow them to lower costs and increase the number of users served, and each of them allocated bandwidth.

It is obvious that the planned range of services and necessary bandwidth for them to provide the services, have a direct influence on the choice of technology FTTx. The higher the speed of access and the larger set of services, the closer to the terminal must be suitable optics, namely the need to use technology FTTH. If the priority is the preservation of the existing infrastructure and equipment, the best choice would be FTTB.

The traditional concept of FTTB solves the problem of supplying optics in apartment buildings or offices. Wiring inside the house can be carried out using copper balanced pairs (common solution) or VDSL-modem (the decision is more typical for FTTC).

The concept does not include FTTB establishment of a special station equipment or user terminals. Inside the building is used network equipment and "copper" in the layout of the room. In the residential sector - set top box STB, if the operator provides Triple Play / IP-TV.

The most perspective solution is the concept of optical networks FTTH.

Experts list the following advantages of the architecture FTTH:

- FTTx provides high bandwidth;
- It is a fully standardized and the most promising option;
- FTTH solutions provide customers mass servicing at a distance of 20 km from the communication center;
- It's can significantly reduce operating costs - by reducing the area of technical facilities, low energy consumption and the actual costs of technical support.

Optical access networks technologies

Optical access networks are most commonly used with three integrated technologies:

- Micro SDH;
- Active Optical Network (AON, Active Ethernet, AE);
- Passive Optical Network (PON).

Micro SDH

In the eastern and south-eastern Asia, as well as in the United States Micro SDH technology is used. Single plate multiplexers of the STM - 1/4 level with the integration of Fast Ethernet and E1 circuits are commonly used topology of the "ring" (sometimes "point to point" or "linear "). Such a network has a good fault tolerance, manageability and easy to maintain. However, the deployment of a full ring with a large number of users associated with significant capital costs (the cost of one multiplexer - 3000...$ 6000), significant difficulties arise when connecting new customers and creating new segments of the network.

Placing of multiplexing equipment requires a stable power supply, temperature control of the environment, protection against unauthorized access. Besides technology SDH is initially optimized for transmitting telephone traffic was not the best transport technology for data transmission (Fast Ethernet, Gigabit Ethernet) and video. Consequently, such solutions is acceptable to the business sector («ring», «point to point») or inter station connections of urban network (MAN) («Ring").

AON

Well established in the local networks, Ethernet technology begins to "go out" from a house and it is used extensively in service provider networks at various levels. It is relatively inexpensive, allows to replace the hardware and software access speed over a wide range, and supports all services (data voice and video) and all types of transmission media (copper, fiber optic cables), supports sequential hierarchy 10/100/1000 Mbps.

New functional capabilities make it easy to add new services such as IP-telephony, Ethernet-video, dedicated channels with guaranteed bandwidth, etc.

This technology is most popular in the countries of northern and central Europe (Sweden, Norway, Germany, Austria, etc.).

Alliance EFMA (Ethernet in the First Mile Alliance) was founded in 2001, has made a significant contribution to the development and standardization of the use of different varieties of Ethernet in the access networks. In optical networks, there are commonly used topologies, such as "point to point" or "Star". This topology is simple in design and maintenance of the network, it allows you to limit or increase the speed of information transmission to each user.

However, the technology of active optical Ethernet networks has several disadvantages. Costs for active equipment are quite large, and it requires the installation of guaranteed power supply. In optical cables it is used by a large number of fibers, and although the cost is not too high, the cost of construction and installation works and measurements will be significant. It may be problematic to expand the network, and to lay in the cable the substantial margin of fibers, based on the connection of new subscribers is not very economical.

The practice of building access networks in our country has shown that optical Ethernet is the most effective with scheme FTTB (more precisely, "fiber to the building") in new construction, with good cable infrastructure when there is no need to save much fiber, and if there is a possibility of placement and organization of the active power equipment.

PON

One of the most popular technologies for optical access networks is the PON (Passive Optical Network). Her idea is to build an access network with high bandwidth with minimal capital costs. This solution provides for the establishment of an extensive network of (mostly with a tree topology) with no active ingredients - on passive optical splitters. Information for all users is transmitted simultaneously with the time division from the main station - the optical line terminal (OLT, Optical Line Terminal) - to end optical network units (ONU, Optical Network Unit).

Transmission and reception in both directions is usually done over a single fiber, but at different wavelengths. In a direct current (from the subscriber station) using a wavelength 1490 nm or 1550 nm, and in the reverse direction (from the subscriber to the station) - 1310 nm.

Optical power through the output OLT at the network nodes is divided (uniformly or non-uniformly) so that the input level of ONU was approximately the same. Quite often, one of the wavelengths (usually 1550 nm) is allocated for transmission to all subscribers of a television signal.

Then at the station WDM optical multiplexer is set for combining the transmitted signals 1310 (voice, data) and 1550 nm (video). Total it is possible to connect up to 32 (in some species - up to 64) subscribers.

As we can see from the figure 7.2, direct stream contains data simultaneously for all ONU, but each terminal device extracts the information only for its terminal. In the opposite direction from each ONU sends subscriber information in its time and then after combining of the total flow it contains signals from all users.

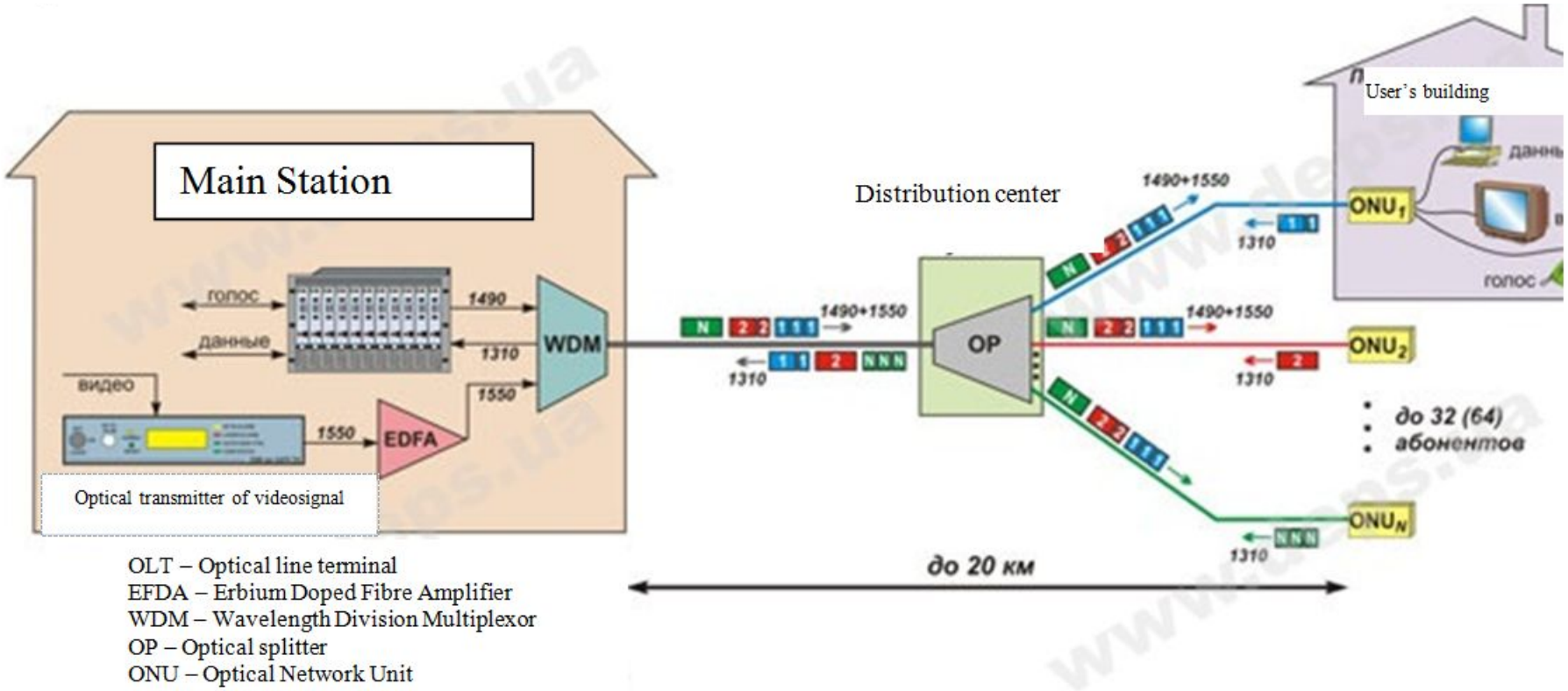

Fig. 7.2 – Variant of PON network construction

Advantages of PON are:

- Minimal usage of active equipment;
- Minimization of cables infrastructure;
- Low cost of equipment;
- Easy control of all network elements;
- Possibility of integration with cable television;
- Good scalability;
- High density of subscribers ports.

At the same time, it is necessary to consider it's features comparing with "point-point" lines:

- The collective performance of the channel between the users - the general environment may not be suitable for the customer in terms of safety;
- Passive splitters are making difficulties in diagnosing of optical line;
- Possible impact of equipment failure of one subscriber on the work of others;
- Low efficiency during realizations of small projects.

PON classification

PON standards recommended by ITU-T

The first steps in PON technology (passive optical networks) took place in 1995, when a group of seven companies (British Telecom, France Telecom, Deutsche Telecom, NTT, KPN, Telefonisa and Telecom Italia) has created a consortium to implement ideas of multiple accesses over a single fiber. This organization was supported by ITU-T; it was called FSAN (full service access network).

.

APON was first developed technology, based at the transmission of information in the structure of the ATM cells with service data. In this case it was provided speed of forward and reverse flows of 155 Mbps (symmetric mode) or 622 Mbps in the forward flow and 155 Mbps in the opposite direction (asymmetric mode). To avoid overlapping data from different users, OLT directed service messages to each ONU with permission to send data. Currently APON in its original form is not used practically.

APON allows dynamic allocation of the DBA (dynamic bandwidth allocation) between the different programs and different ONT and is designed to provide both broadband and narrowband services.

Equipment APON from different manufacturers support backbone interfaces: SDH (STM-1), ATM (STM-1/4), Fast Ethernet, Gigabit Ethernet, video (SDI PAL), and subscriber interfaces E1 (G.703), Ethernet 10/100Base -TX, telephony (FXS).

Further improvement of the APON technology has **created a new standard - BPON**. In March 2001, appears recommendation G.983.3, enshrining the notion of BPON (broadband PON) and adds new features to the standard PON:

- Transfer of a variety of applications (voice, video, and data) - this is actually allowed manufacturers to add the appropriate interfaces on the OLT to connect to the backbone network and to connect the ONT to the subscribers;

- Expansion of the spectral range is an opportunity for additional services at other wavelengths in the same PON tree, such as broadcast television at the third wavelength (triple play).

- Here the rate of the forward and reverse flow increased to 622 Mbps in a symmetric mode or 1244 Mbps and 622 Mbps in the asymmetric mode. You can transfer the three main types of information (voice, video, data), and for the video stream is selected wavelength of 1550 nm. BPON allows you to organize the dynamic allocation of bandwidth between individual subscribers.

GPON technology inherits line APON - BPON, but with a higher data rate - 1244 Mbps or 2488 Mbps (asymmetric mode) and 1244 Mbps (symmetrical mode). Of reference was the basic protocol SDH (or rather GFP protocol) with all the advantages and disadvantages arising from it.

It is possible to connect up to 32 (or 64) of subscribers up to 20 km (expandable up to 60 km). GPON supports both traffic of ATM, and of IP, voice and video (encapsulated into frames GEM - GPON Encapsulated Method), and SDH. The network operates in a synchronous mode with a fixed frame length. NRZ line code and scrambling provide high bandwidth efficiency.

G-PON technology supports all the existing services, which makes it attractive to business problems and to solve the "last mile" problems to the end user. It supports services such as high-speed Ethernet, digital telephony, high-quality TV channels, etc. Technology G-PON supports 7 combinations of the rate for the upstream and downstream:

- 155 Mbps up, 1.2 Gbps down;
- 622 Mbps up, 1.2 Gbps down;
- 1,2 Mbps up, 1.2 Gbps down;
- 155 Mbps up, 2.4 Gbps down;
- 622 Mbps up, 2.4 Gbps down;
- 1.2 Mbps up, 2.4 Gbps down;
- 2.4 Mbps up, 2.4 Gbps down.

PON standards recommended by IEEE

Successful use of Ethernet in local area networks and building on their basis of optical access networks has identified the development of a new standard in 2000 - EPON. Such networks are basically designed for data transmission at the forward and backward streams 1 Gbps IP-based protocol for 16 (or 32) subscribers. Based on the transmission speed it is called GEPON (Gigabit Ethernet PON) which also refers to the IEEE 802.3ah standard

Also it is developed a standard IEEE 802.3av, designed for a speed of 10 Gbps - 10GEPON.

Transmission distance in such systems is up to 20 km. To avoid conflicts between the signals of the reverse flow, control protocol uses a special set of nodes (Multi-Point Control Protocol, MPCP).

In GEPON it is supported the operation of the exchange of information between users (bridging).

The main property of EPON architecture is that t in the PON tree frames Ethernet spread. Thus, there is no fragmentation of the Ethernet frame as they pass through the EPON network, as in the architecture of APON. The lack of fragmentation makes the expected standard EPON most similar to the standard Ethernet IEEE 802.3.

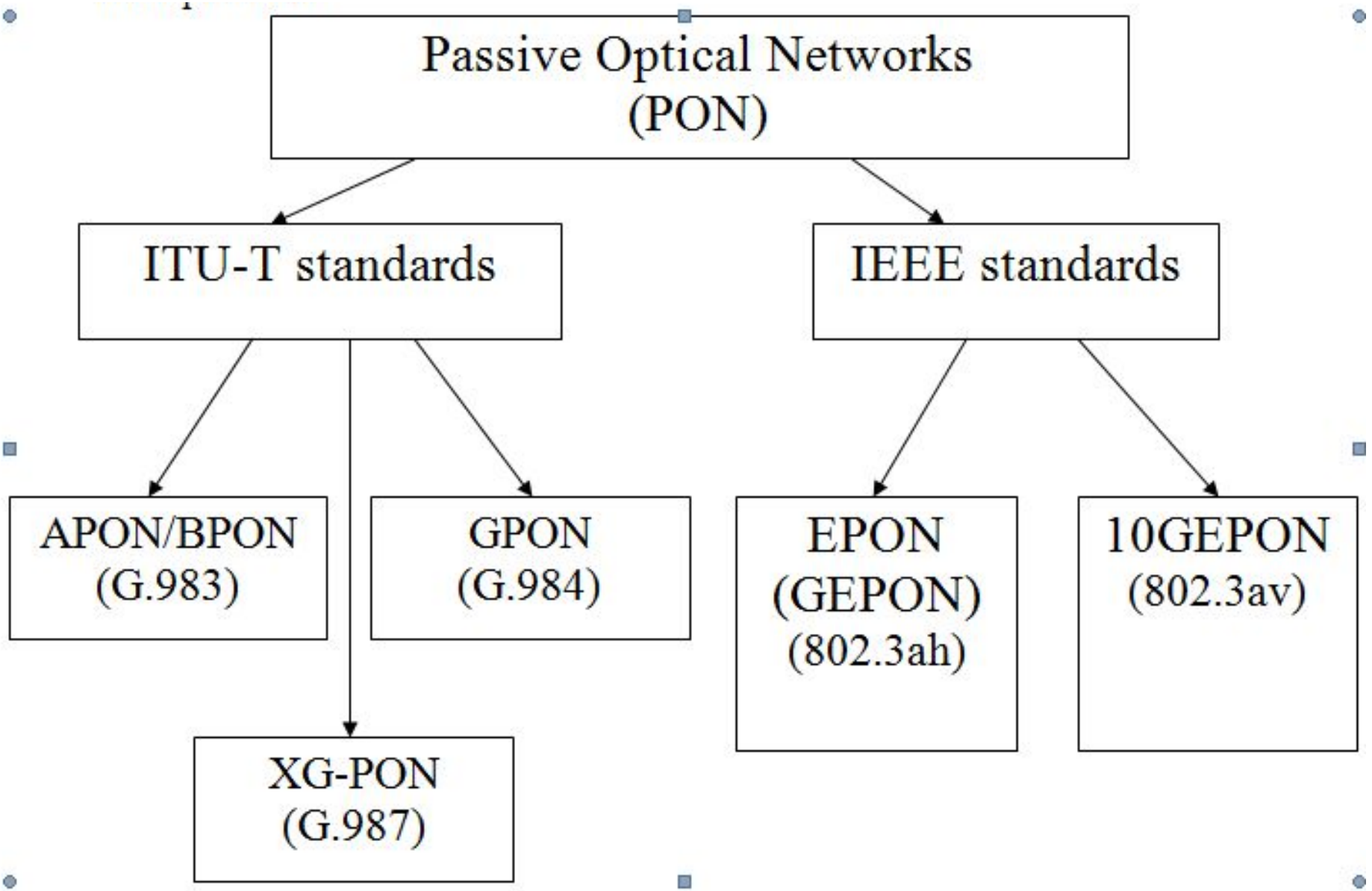

Figure 7.3 – Classification of Passive Optical Networks technologies

Table 7.1 - Comparative analysis of PON technologies

Characteristics	**EPON (GEPON)**	**GPON**
Transmission rate forward/reverse stream, Mbps	1000/1000	Max: 2488/2488
Base protocol	Ethernet	SDH (GFP)
Linear code	8B10B	NRZ
Maximal number of subscribers	16 (32)	64 (128)
Maximal radius of a network, km	10 (20)	20
Wavelength, forward/reverse stream, (video), nm	1490/1310 (1550)	1490/1310 (1550)
Dynamic range, dB:		
	Interface PX-10 (10 km) – 5-20	class A – 5-20
	Interface PX-20 (20 km)– 10-24	class B – 10-25
		class C – 15-30
Application	IP, data	Any
Error correction FEC	no	necessary
Wavelength, forward/reverse stream, nm	1550/1310 (1310/1310)	1550/1310 (1480/1310)
Dynamic band distribution	support at higher levels	yes
IP-fragmentation	no	yes
Data protection	no	Ciphering with opened keys
Reserving	no	yes
QoS	low	high

So, from all mentioned above we can formulate following conclusions:

- When construction large distributed networks, the best option would be to use GPON technology and its higher-speed successor XG-PON;

- If you want to build a small or medium sized network-oriented at IP-traffic and IPTV, then the best option would be to use GEPON or 10GEPON technology, whose equipment is cheaper;

- All PON technologies, regardless of the standard, have the potential to build-up rate due to application of WDM at low cost for upgrading.